

[54] **HYDRAULIC CONTROL DEVICE FOR TRANSMITTING MEASURING VALUES FROM THE BOTTOM OF A WELL TO THE SURFACE AS PRESSURE PULSES THROUGH THE DRILLING MUD**

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[56] **References Cited**

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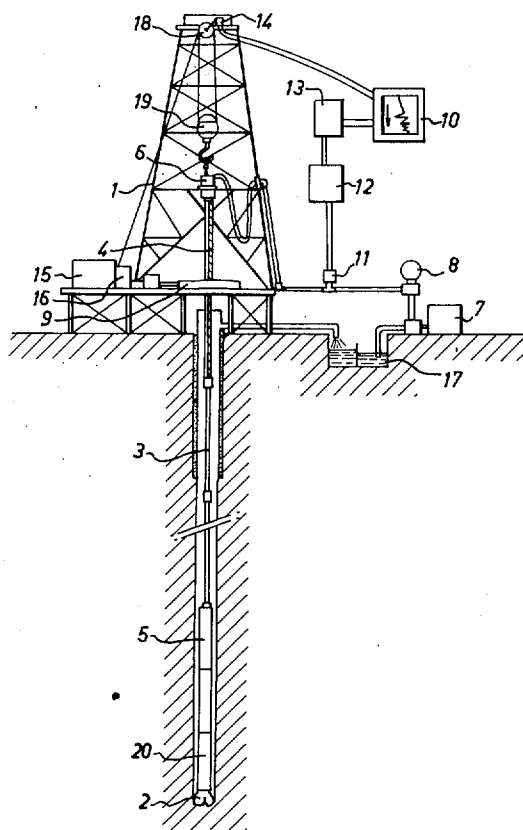
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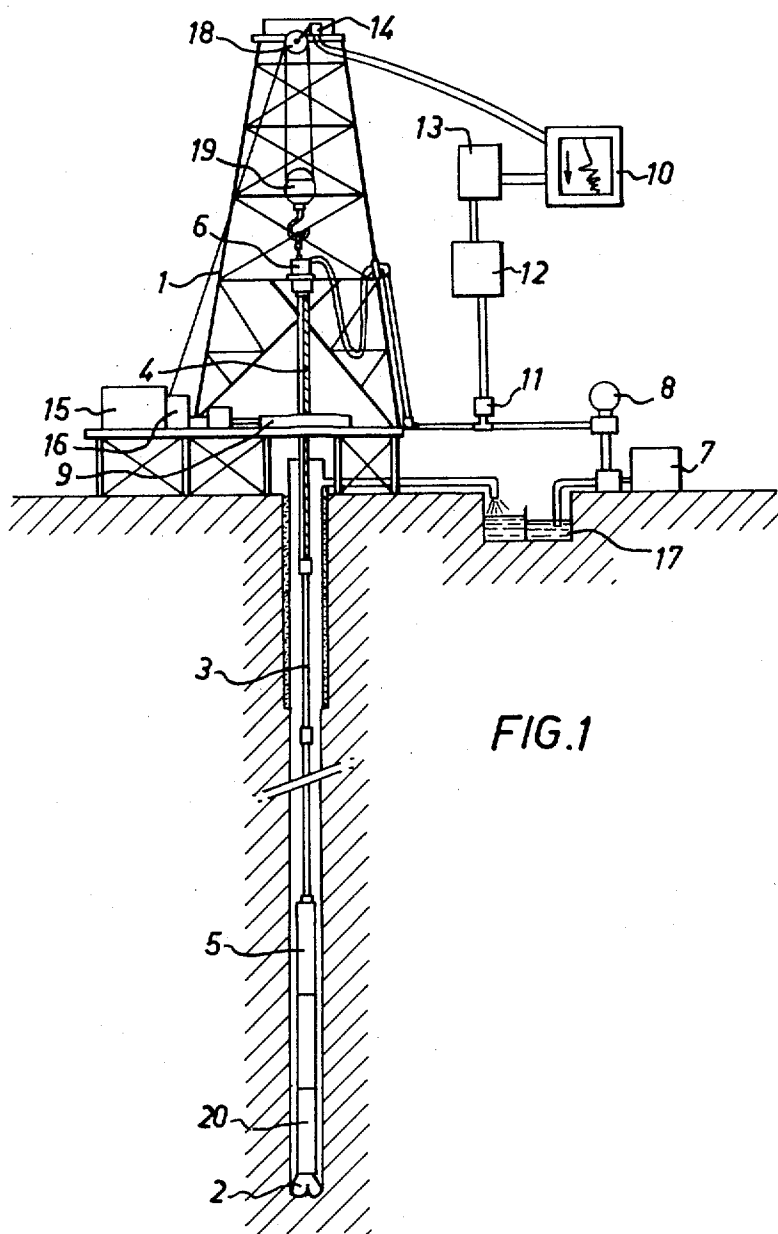
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[57] ABSTRACT

Device for transmitting information with respect to measuring values of parameters of a drilling operation from the bottom of the well to the surface in the form of pressure pulses through the mud stream comprising flow limiting means in the path of said stream controlled by electric signals derived from the measured values of said parameters, hydraulic power-accumulator means storing under pressure a control fluid forced therein by pump means energized by a bottom turbine driven by the mud stream and releasing said pressurized fluid through said control means in response to said electric signals, and surface means for sensing said pressure pulses and converting the same to electric values representative of the measured values of said parameters.

7 Claims, 3 Drawing Figures





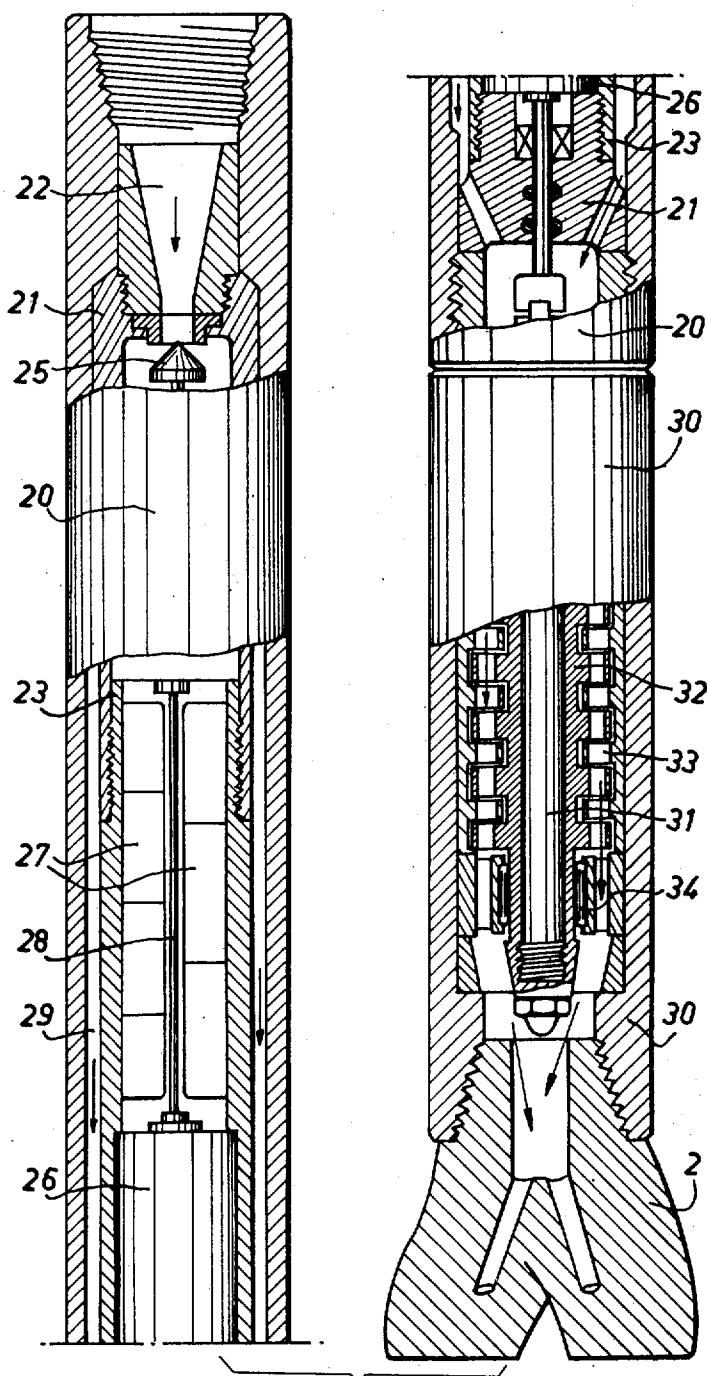
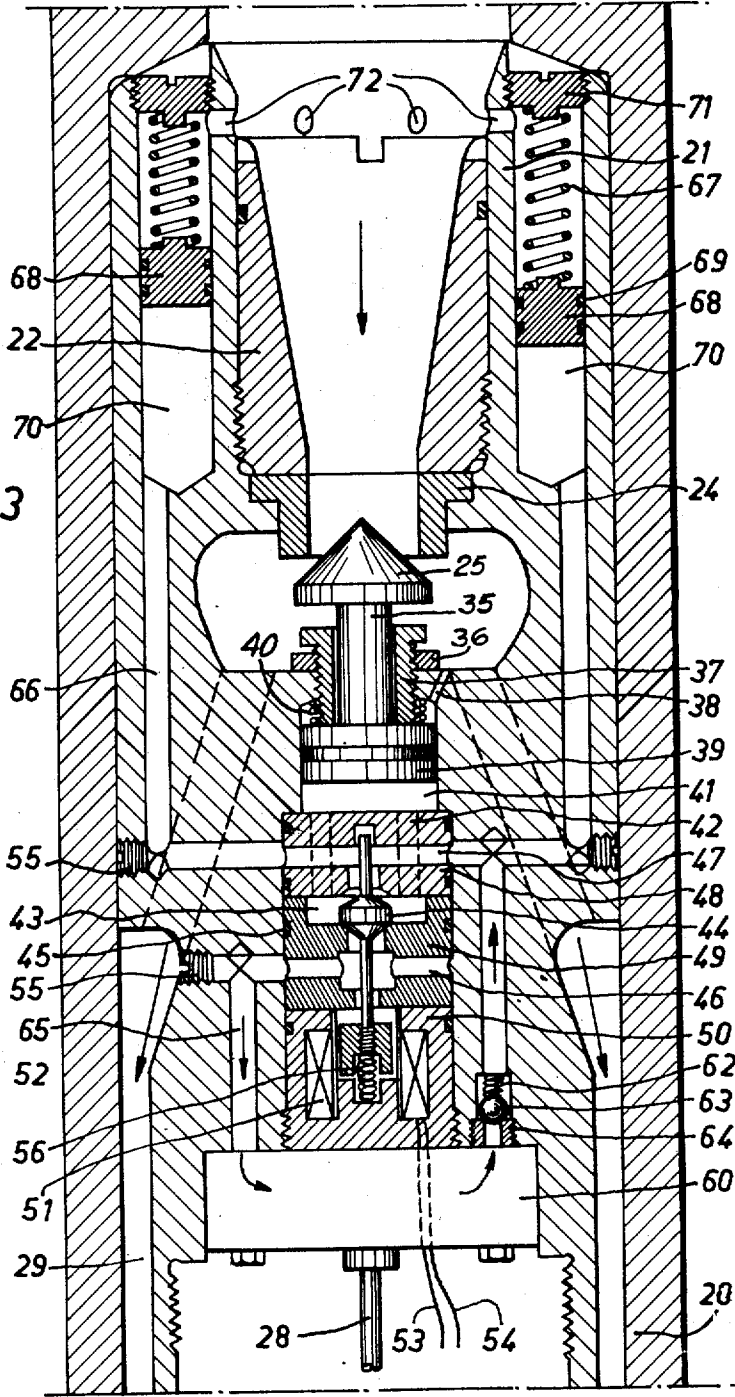


FIG. 3



HYDRAULIC CONTROL DEVICE FOR TRANSMITTING MEASURING VALUES FROM THE BOTTOM OF A WELL TO THE SURFACE AS PRESSURE PULSES THROUGH THE DRILLING MUD

This invention relates to the drilling of wells and particularly to a device for immediately transmitting to the surface instantaneous values of the torque, the weight on the tool, the rotation speed thereof or any other value of a specific parameter related to the drilling conditions.

When the drilling is carried out with the use of a hydraulic turbine energized by the mud stream, it is difficult to determine with accuracy the variations of the resistant torque of the tool and of its rotation speed.

In fact, these parameters are dependent on the force of application of the tool against the bottom of the bore hole, on the nature of the traversed formations and on the wear condition of the tool.

Thus, in the case of deep wells and when the nature of the traversed formations is unknown, it happens frequently that the tools are working in bad conditions and accordingly are prematurely worn. This condition of wear cannot be detected at the surface directly but in the form of a decrease in the penetration rate of the tool which causes the drill man to stop the work and withdraw the entire drill string out of the bore hole.

This results in a considerable loss of time, the decrease of the penetration rate being not necessarily due to a premature wear of the tool.

Many devices have been proposed for measuring, from the surface, the resistivity of the formations traversed during the drilling operation and even for determining the degree of wear of the rollers of the drill bit by comparing their rotation speed with that of the drill string. Such devices generally comprise one or more transducers for converting the value to be measured (resistivity of the earth formation, torque, weight on the tool and the like) to an electrical value in the form of a voltage or a current intensity. These transducers are adapted to the kind of value to be measured and are well known in the art. Such systems also comprise an electronic assembly for amplification and conversion of the signal, fed with a special battery adapted to work at a high temperature. The assembly of the battery and amplification means is generally housed in the central portion of a special drill collar forming part of the drill string and placed at the lower portion thereof above the drilling tool. The converted signal issued from the amplifier is applied to a device for controlling a flow-limiting member placed on the path of the mud stream so as to produce abrupt variations of the resistance to the flow of the drilling mud. It has already been proposed to realize this control device as a hydraulic assembly using a control fluid separate from the drilling mud and energized by the latter through elastic cylindrical membranes.

The power of the mud stream is thus used for actuating a valve in the mud stream, in synchronism with the signal representing the value to be measured, as issued by the above-mentioned electronic assembly. The hydraulic assembly is generally placed within a drill collar just above the drill collar which contains the electronic assembly.

The pressure variations in the mud stream provide a coded representation of the drilling parameter measured at the bottom and are sensed at the surface by suitable pressure transducers which convert them to signals, particularly electric signals, which are recordable (see in particular U.S. Pat. No. 2,524,031 with particular reference to the part of the specification describing FIG. 3).

Such a device suffers from various drawbacks, a first of which is the poor yield of the system for forcing back the control fluid to the tank, a second drawback is common with the prior devices, wherein the flow rate limiting device is actuated by the drilling mud.

It is an object of this invention to provide a device whereby the above drawbacks of the prior devices are avoided.

More particularly, one of the objects of the invention is to provide a device adapted to make use of the power of the drilling fluid for transmitting information measured by suitable transducers, the operating conditions of which are not disturbed by the variations of the flow rate, the pressure or the composition of the drilling mud.

According to this invention the device for transmitting to the surface parameters values measured at the bottom of a well during the drilling operation and converted to pressure pulses applied to the drilling mud and adapted to be sensed at the surface, is placed at the lower end of the drill string and comprises at least one measuring apparatus, means for converting the measuring values obtained from said apparatus to corresponding measuring signals and a flow-limiting member placed on the path of the drilling mud stream and adapted to generate pressure pulses therethrough.

This device is remarkable by the combination of means for controlling said flow-limiting member comprising at least one capacity of pressurized control fluid, whose volume may be increased by displacement of a movable partition against the antagonistic action of return means, a pump energized by a turbine driven in rotation by the drilling mud, said pump being adapted to force under pressure the control fluid into said capacity, and an electrovalve having a first operating position at which the pressurized fluid contained in said capacity acts on said flow-limiting member and a second position at which the control fluid can be forced under pressure into said capacity against the antagonistic force of said return means, said electrovalve being actuated by means of said measuring signals.

According to a preferred embodiment of the invention, the side of said movable partition opposite to that on which is exerted the pressure of the control fluid in said capacity, communicates with the mud stream above said flow-limiting member.

Of course this invention is not limited to the apparatus described in the illustrated embodiment and includes in its scope all the alternative embodiments making use of other compensating systems with fluid storage, other electrovalves or other pumps than those shown in the accompanying drawings.

The characteristic features of the invention will appear more clearly from the appended drawings wherein:

FIG. 1 is a diagrammatic cross-sectional elevation view of a bore hole and the associated drilling apparatus.

FIG. 2 shows the location of the transmitting elements inside the special drill collar.

FIG. 3 is a cross-sectional view of the valve operating mechanism according to the invention.

The drilling apparatus shown in FIG. 1 comprises a derrick 1 carrying a drilling tool or drill bit 2 through the intermediary of drill stems 3. The drill stems assembly and the tool are suspended from the movable block 19 of winch 16 and are driven in rotation by a square kelly 4 slidable through, but integral in rotation with the rotary table 9 placed at the foot of the derrick.

The weight on the drilling tool is given by drill collars 5 and is adjusted by the traction force exerted on the drill string 3 by means of the winch 16. Said winch is also used for disengaging the assembly of the stems and drill collars, detachable by elements, from the well, when it is desired to change the drilling tool 2. The rotary table 9 and the winch 16 are actuated by a motor assembly 15.

The drill cuttings produced by the operation of the tool 2 are carried away by a large mud stream, raising up through the free annular space between the stems and the walls of the well and which is poured into a filtering and decanting system diagrammatically shown by the mud tank 17. The cleaned mud is sucked by the pump 7, provided with a pulsation absorber 8, forced under pressure toward the revolving connector or injection head 6 and from there to the drilling tool through the inlet duct of the drill stems 3.

The transmission to the surface of the drilling parameters is carried out by means of a measuring device associated with a transducing system generating variations of the mud pressure indicating the measured value, and generally housed in a special drill collar 20. These mud pressure variations are transmitted through the mud contained in the inner duct of stems 3 and received by the pressure transducer 11 mounted on the feeding pipe of the injection head.

The transducer 11 converts the variations of the mud pressure to electric signals having an intensity proportional to the pressure prevailing in the duct. The amplifier 12 comprises a filter for removing the parasitic signals due to the steady pressure pulsations of the pump which have not been completely absorbed by capacity 8.

The decoding device 13 generates, in response to a series of pressure pulses, an electric signal whose intensity is representative of the measured value of the drilling parameter.

This value may be the average of the instantaneous successive values over the coding transmission period or the instantaneous value at the beginning of each transmission, or any other value resulting from the combination of values of different parameters.

The value of the parameter is recorded on a paper strip driven at a linear speed controlled by the transmission device 14 connected to the stationary block 18 so as to be made proportional to the penetration rate of the tool.

The recorder 10 thus provides directly the diagram of the formation traversed by the tool.

FIG. 2 shows the bottom transducer system, generally located above the tool 2, at the lower part of the drill collars 5. The transducer system usually comprises three drill collar elements respectively containing the sensor of the value to be measured (weight,

torque, resistivity . . .), the transducer unit itself and the turbine as a source of mechanical power. Only these two last elements are shown in FIG. 2. The element 30 is the turbine body containing stationary blades 33 and bearings 34. The turbine shaft 31, which carries movable blades 32, is guided through bearings 34 and is provided with stop members, not shown. The upper portion of the turbine shaft 31 is provided with coupling means driving the shaft of an alternator 26 placed at the lower end of the drill collar element 20.

The transducer system is contained in the mud-proof casing 23, fastened to the center of the drill collar element 20 by means of end connectors 21. The annular space 29 between the casing 23 and the drill collar 20 forms a passageway for the drilling mud feeding the turbine and the tool, the travel path of which is indicated by arrows.

The position of the different parts of the transducer system generally conforms with that shown in FIG. 2. The clack valve 25 and the nozzle 22 through which the mud passes are at the upper level. Just below is the mechanism for actuating the clack valve shown in more detail in FIG. 3. At the center of the sealed casing 23 are a number of boxes 27 containing electronic circuits for converting to electric signals the values measured by the sensors and for regulating the current produced by the alternator. This part is traversed by a driving shaft 28, optionally a flexible shaft, adapted to drive a hydraulic pump generating the mechanical power required by the clack valve actuating mechanism.

When the sensor of the drilling parameter has no electrical or mechanical connection with the exterior of the drill collars, for example in view of measuring the inclination of the well with respect to a vertical line, it may be entirely enclosed in a box 27 with no need for a special drill collar element.

The alternator 26 is generally housed at the lower end of the sealed casing 23 with its shaft passing across the end connector 21 through an opening provided with suitable sealing devices known in the art.

FIG. 3 shows in detail the arrangements of the special drill collar at the upper part thereof. The end connector 21 is provided internally with a cylindrical housing 41 wherein can be displaced a piston 39 integral with the stem 35 of the clack valve 25, and receives the valve seat 24. The clack valve and its seat are both made of a special steel having a high resistance to abrasion. The nozzle 22, through which is supplied the drilling mud, is screwed on connector 21 for holding seat 24 and the internal section of said nozzle progressively decreases in the direction of the flow so as to increase the velocity of the drilling fluid without substantial pressure loss.

After the clack valve, the fluid passes to the annular space 29 formed between the sealed casing 23 and the internal wall of the drill collar element 20, through a plurality of openings provided in connector 21. According to the embodiment shown in FIG. 3, the clack valve 25 is lifted up by piston 39 when the electrovalve slide is at its low position, i.e. when coil 51 is energized by a signal or electrical current issued from the electronic apparatus through conductors 53 and 54. In fact, at this position of the slide, the storage capacity 70 of control fluid, e.g. oil under pressure, communicates with the cylinder 41 through ducts 66, 47 and 42. The

oil capacity 70 is formed of several cylinders distributed around the nozzle or end connector 22, each containing a piston 68 provided with sealing joints 69 and pushed by a spring 67 taking its bearing on a plug 71. The top of each cylinder communicates with the mud inlet, above the nozzle 22, through an opening 72 and the static pressure of the mud is thus transferred to the oil of the storage capacity. Similarly the mud static pressure prevailing under the nozzle is transferred to the upper face of piston 39 in the housing of the return spring 40 through openings 38. When the clack valve 25 is remote from the seat 24, the pressures prevailing near the openings 38 and 72 are very close to each other but the forces exerted by the springs 67 on the pistons 68 generate in the oil capacity 70 a residual pressure higher than that produced by the force of the return spring 40 on piston 39. As a result, as soon as the core 52 of the electrovalve is attracted and the capacity 70 communicates with cylinder 41, the clack valve is lifted up towards its seat, said displacement having no tendency to establish an equilibrium state.

As a matter of fact, the action of the clack valve results in a mud pressure increase at the level of ports 72, said pressure increase being transferred to the oil of the compensating cylinders 70 through pistons 68 with the same result as if the clack valve was pressed against its seat 24 by the drilling fluid itself.

Such a device produces rapid and controllable fluctuations of the drilling mud pressure. By limiting the stroke of the clack valve by an adjustable stop member 37 locked by nut 36, the pressure increase is limited to a predetermined value. This increase is maintained as long as the electrovalve 50 is energized by a current issued from the electronic apparatus housed in boxes 27 and representing the coded form of the measuring value, as obtained by a sensor, of a characteristic parameter of the drilling operation.

For a greater convenience in the manufacture of the electrovalve, elements 48, 49 and head 50 thereof are provided with sealing rings 45 and introduced in a bore of connector 21. All the ducts open in said bore and their external end parts are closed by plugs 55 after machining.

When the slide 44 of the electrovalve is pushed back to its rest position by spring 56, in the absence of current through coil 51, the cylinder 41 is no longer subjected to the pressure prevailing near the ports 72 and communicates with the pump 60 which tends to empty it through ducts 42, 46 and 65. The oil is returned to the compensating cylinders 70 through a non-return valve diagrammatically shown at 62, 63, 64. The pump is mechanically driven by the turbine through the intermediary of shaft 28 and is provided with an inner pressure valve limiting the pressure to a value slightly greater than the maximum pressure difference generated in the mud stream by the lifting of the clack valve 25.

The piston thus returns to its initial position as quickly as allowed by the oil viscosity and the pump flow rate.

The above-described device thus produces a very sharp pressure variation in the mud stream in response to a simple electric signal, by the use of well known elements of common utilization in the art of hydraulics, which is a condition of safe operation.

The combined use of a hydraulic transmitter and an apparatus sensing the pressure changes of the drilling mud at the surface provides a fluid connection which is entirely free from the troublesome requirements of the electrical devices with conducting cables and is therefore perfectly well adapted to the requirements of the conventional rotary drilling.

From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention and without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions. Consequently, such changes and modifications are properly, equitably and intended to be within the full range of equivalence of the following claims.

What we claim is:

1. An apparatus for telemetering, from a bore hole, signals measured in a well during drilling operation therein, said signals being in the form of pressure impulses imparted to drilling fluid and capable of being detected at the surface of the well, said apparatus being located at the lower end of a drill string and including at least one measuring means for generating electric signals representative of a parameter being measured within said bore hole and means, responsive to said electric signals, for imparting pressure impulses to said drilling fluid comprising:

a drill string section;

a drill fluid valve arrangement disposed in a path of the drilling fluid, said valve arrangement including a stationary seat, a plunger head and a first piston integral with said plunger head for effecting the application of pressure impulses to said drilling fluid; and

means for actuating said valve arrangement comprising:

means for storing the capacity of fluid under pressure, the volume of which is adjustable, a second piston, displaceable within said storing means, for controlling the volume of fluid within said storing means, and a resilient means, connected with said second piston, for exerting a predetermined pressure upon said piston, for maintaining said second piston displaced a predetermined amount within said storing means, said storing means further including means, communicating with said drilling fluid on the same side of said second piston as said resilient means, for imparting the pressure of said fluid on said second piston,

a first cylinder, within which said first piston is displaceable and being controllably communicable with said storing means, for permitting the application of fluid pressure to said first piston, to effect the movement of said plunger head with respect to said seat in response to said fluid pressure,

a turbine over which said drill fluid passes being driven in rotation thereby,

a pump, energized by said turbine, for pumping said fluid under pressure into said storing means, and

an electrovalve means, responsive to said generated electric signals, for effecting the application of said fluid pressure to said first piston

in a first position thereof, whereby fluid from said storing means enters said first cylinder and acts upon said first piston to move said plunger head toward said seat, and for effecting the flow of fluid from said first cylinder to said pump in a second position thereof, whereby said pressurized fluid is pumped into said storing means and said first piston together with said plunger head withdraws from said seat, to permit said drilling fluid to pass therethrough.

2. An apparatus according to claim 1, wherein said storing means comprises a plurality of fluid cylinders and corresponding ducts for communicating with said first cylinder in which said first piston is displaceable.

3. An apparatus according to claim 2, wherein said electrovalve means comprises a first valve inlet connected with said ducts for permitting fluid flow to said first cylinder for said first position of said valve and a second valve inlet for exhausting said fluid from said first cylinder into said first pump for a second position of said valve.

4. An apparatus according to claim 3, wherein said electrovalve means includes a slide means disposed in a chamber between said first and second inlet and coupled to an electromagnet connected through a displaceable rod member and wherein said chamber further includes passages communicating only with said first cylinder, for permitting the transmission of pressurized fluid to and from said first cylinder.

5. An apparatus according to claim 4, wherein said electrovalve means further includes additional ducts disposed beneath said second inlet and communicating with said second inlet for permitting the transfer of fluid from said chamber through said additional ducts to said pump.

6. An apparatus according to claim 5, further including a drill fluid passageway surrounding said valve arrangement and having a first cavity in which said plunger is located, the plurality of drill fluid conduit extending therefrom and communicating with a substantially cylindrical gap surrounding said pump, said gap

extending down through said turbine, through an additional plurality of drill fluid conduits.

7. A device for transmitting to the surface values measured at the bottom of a well during a drilling operation, in the form of pressure pulses imparted to the drilling liquid and adapted to be sensed at the surface, said device being placed at the lower portion of the drill string and comprising a drill string section, at least one measuring apparatus, means for converting the measuring signals and in response to the pressure of a control fluid displaceable valving device comprising a plunger head cooperating with a stationary seat and integral with a piston movable in a cylinder, said plunger head being placed on the path of the drilling fluid stream and adapted to generate pulses therethrough, means for actuating the valving device comprising:

at least one capacity of pressurized control fluid whose volume may be increased by displacement of a piston, freely displaceable against the antagonistic action of a spring, and upon which a pressure of the drilling fluid is acted equal to the pressure prevailing in the vicinity of the valving device in its open position,

a cylinder, wherein the piston integral with the plunger head can move, said cylinder communicating alternatively under control of an electrovalve with said capacity of pressurized control fluid or with a pump inlet,

a pump energized by a turbine driven in rotation by the drilling liquid, said pump being adapted to force under pressure the control fluid from the cylinder into said capacity,

an electrovalve having a first operating position at which pressurized fluid contained in said capacity fills the cylinder and acts on the piston integral with the plunger head, and a second operating position at which the control fluid can be forced under pressure into said capacity, said electrovalve being actuated in response to said measuring signals.

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